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Comparative Study of Infrared Nd:YAG Pulsed Laser Radiation on Pt Thin Film

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Abstract: This paper investigated on infrared Nd:YAG pulsed laser radiation on platinum (Pt) thin films. Pt thin films were deposited on Si by DC magnetron sputtering. Then, the deposited thin films were radiated by infrared Nd:YAG pulse laser at different laser energy. The radiated thin films were analysed based on the electrical and surface morphological properties. Four-point probe measurement shows that, the lowest resistivity was recorded when the energy laser are 110-170 mJ. Surface morphology scanned by scanning electron microscope (SEM) revealed that the surface of sample with lowest resistivity after radiated with laser is smoother than the as-deposited thin films. After laser radiation, the grain sizes of thin films increases due to the grain agglomeration on the surface area.

Keyword: Pt thin films; Nd:YAG; laser radiation; resistivity; surface morphology.

1. Introduction

Photonic devices are new technology, which can create, manipulate and detect light. The advantage characteristics of these devices are bandwidth and data processing is faster, energy efficient, low cost and smaller as compared to conventional device. Photonic devices are often used in combination with mechanical, electronics, embedded software and physical processes in liquids and chemistry. Examples of these devices are light emitting diode (LED), laser diode (LD) and solar cells. Most of these studies have been conducted on metal like Al, Au, and Pt that are commonly used for thin films. The properties of Pt are high density, malleable, ductile, highly unreactive, gray-white transition metal. It is preferred over Au because Au is essentially in-compatible with Si CMOS technology due to its high diffusivity [1].

Deposition technique can be divided into two categories that are physical vapour deposition (PVD) and chemical vapour deposition (CVD). For PVD the example are sputtering [2][3] and thermal evaporation, while for CVD is metal-organic chemical vapour deposition (MOCVD) [4][5]. MOCVD is expensive as compared to evaporation, although it offers high deposition quality. The benefit by using by sputtering is it offers uniform thin films as compared to evaporation, besides sputtering techniques offer better adhesion as compared to evaporation technique [6]. Sputtering is preferred because it offers clean deposition environment under low vacuum conditions.

Solid state laser become a choice for many application based on performance capabilities including wavelength variation, reliable and efficient [7]. Laser radiation can cause some changes on the structural in target material [8]. This is due to the heat transfer for laser beam to the target material.

This study reports on the deposition of Cr/Pt (chromium/platinum) thin films on Si substrate by sputtering technique. The deposited thin films then was treated by laser beam radiation at certain pulse energy. The samples were characterized based on the electrical and surface morphological properties.

2. Methodology

Si substrate were cut into 1×1 cm^2 and cleaned by using heated acetone solution. Cr were deposited on Si substrate followed by Pt thin films using DC magnetron sputtering system (Quorum Q300T D). The thickness of Cr and Pt were fixed at 5 nm and 100 nm respectively at current input of 240 mA. After deposition, the Cr/Pt thin films were radiated with 1064 nm

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pulsed Nd:YAG laser model Litron Nano Series. The laser pulsed energy were varied from 110-300 mJ.

The samples then were characterized based on electrical and morphological properties. The electrical properties of non-radiated and radiated samples were measured using four-point probes for electrical resistivity, sheet resistance and conductivity. The surface morphological were scanned and analyzed under scanning electron microscope (SEM) (Phenom Worlds ProX) for the sample radiated and non-radiated with 110 mJ laser energy at 50000× magnification.

3. Results and discussion

3.1 Electrical characterization

Table 3.1 shows the minimum and maximum value for Pt thin film sample that were deposited on Si using four point probe in resistivity, sheet resistance and conductivity after treated with laser. The energy of laser were varied from 110-170 mJ.

Table 3.1 Electrical characteristic of Pt thin film sputter deposited on Si with radiated pulsed laser.

Parameter	Min	Max
Resistivity (Ω-cm)	3.76×10^{-5}	8.14×10^{-2}
Sheet Resistance (Ω/sq)	3.76	8.14×10^{3}
Conductivity $(\Omega\text{-cm})^{-1}$	1.23×10^{1}	2.66×10^{4}

Figure 3.1 shows the trends of electrical resistivity as a function of laser pulsed energy. The resistivity shows significant increment as laser energy increasing, and sharply increases at highest laser energy. The properties of bulk materials including resistivity, sheet resistance and conductivity of the thin films depends on several factors such as deposition rate, thickness, temperature and grain boundaries. The maximum and minimum values for resistivity is 8.14×10^{-2} and 3.76×10^{-5} Ω-cm respectively. Next, the sheet resistant were 8.14×10^{3} and 3.76 Ω/sq respectively. When low resistivity for Cr/Pt thin films on silicon is measured, high current is needed in current probes to obtain good voltage readings. Small spacing differences in probe can cause the resistivity values to vary widely across a sample values. For the Cr/Pt thin films, it radiated with laser from 110-170 mJ. The lowest resistivity is 3.76×10^{-5} Ω-cm respectively. The resistivity decreases due to the easy flow of charge carrier at grain boundaries.

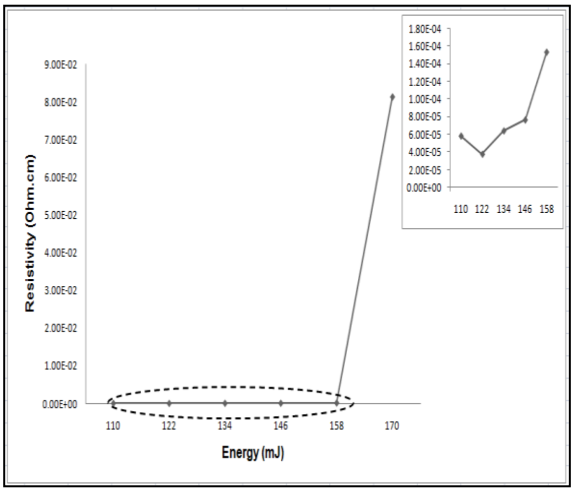


Figure 3.1 Graph of resistivity against laser pulse energy for Cr/Pt thin films deposited on silicon.

Figure 3.2 shows the trend of electrical conductivity as a function as laser energy. The trends of the graph were increase at 122 mJ and drop sharply until 170 mJ. The maximum and minimum conductivity of thin films is 2.66×10^{4} and 1.23×10^{1} Ω-cm^{-1} respectively. The increasing of conductivity was attributed to the higher concentration of charge carrier due to the improved crystalline qualities which make the charge carriers more mobiles.

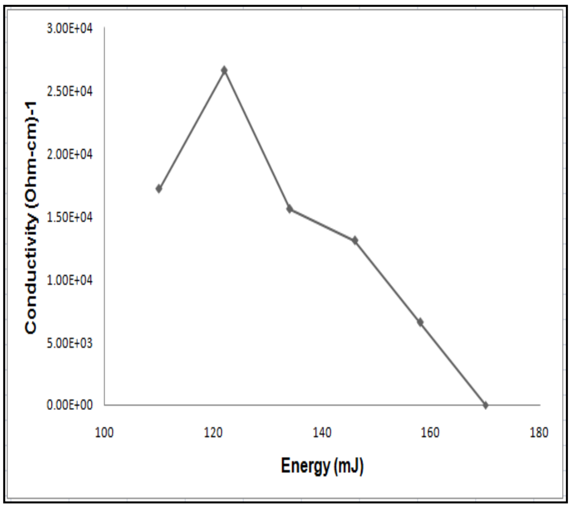


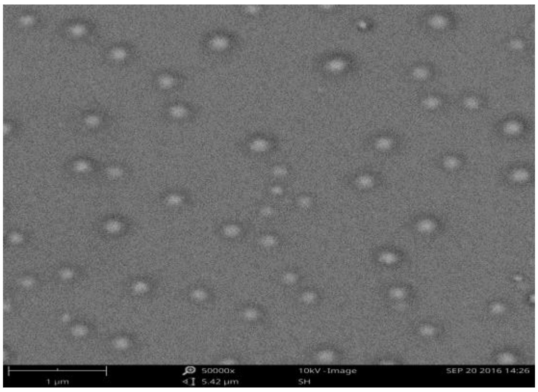
Figure 3.2 Graph of conductivity against laser pulse energy for Pt thin film deposited on silicon.

Heat treatment by using laser radiation is able to improve the electrical characteristics of thin films. Carrier scattering at grain boundaries affect the electrical resistivity. The charge carrier scattering at the grain boundaries and building of potential barrier increases the electrical resistivity. Based on the grain size effects of electrical resistivity, for the bigger size of crystalline grains, grain boundary scattering decreases considerably which reduces the resistivity.

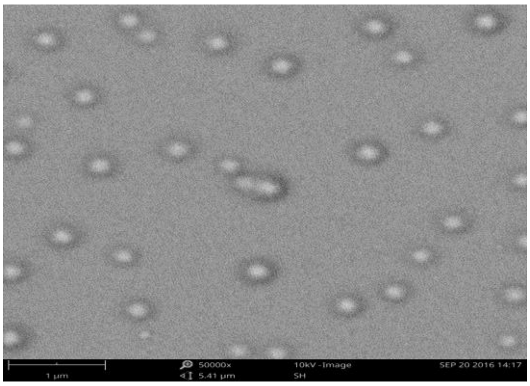
3.2 Surface morphological characterization

Figure 3.3 shows the surface morphology of the as-deposited and laser radiated of Pt thin films at magnification for 50000×. The results showed that the variation of pulsed energy of laser radiated on thin film causes significant effect on Cr/Pt thin films. After treated with the laser, the surface of thin films becomes smoother than the as-deposited due to the agglomeration of surface grain with the neighbouring grains. Grain boundary might cause charge carrier scattering. As the thin films were radiated with Nd:YAG laser, the refractive indices increases due to the increment of film density. After laser radiation, the grain sizes of thin films increases due to the grain agglomeration. As the laser power increased, the melting point of thin films were increased and consequently led to the migration of the grain boundaries with another to form new boundaries. This phenomenon improved the ductility of material. The presence of grains might be attributed to the agglomeration on the surface of thin films that were ejected [9].

The SEM images of the as-deposited Cr/Pt thin films show no cracks or holes generation. In addition, for thin film after treated with laser, its surface show cluster. Based on Ausama *et al.* and her team, it founds that laser radiation results in the change of the films to big cluster diameter having clears boundaries between clusters [10]. When using powerful laser the absorbed energy is converted into heat, causing localized high temperature and surface vaporization resulting on the removal of Pt thin films from Si substrate [11]. As a consequence the Pt thin films damaged due to the laser ablation and darker region all around the surface. The surface grain sizes were increases due to the grain agglomeration.



(a)



(b)

Figure 3.3 Surface morphological of Pt thin film deposited on Si magnification is 50000× (a) as-deposited and (b) radiated with 110 mJ laser energy.

4. Conclusion

In this study, laser radiation affected the electrical and surface morphological properties of Cr/Pt thin films deposited on Si substrate. At different laser energy treated on thin films, it shown that, the lowest value for resistivity was achieved at 3.76×10^{-5} Ω-cm (110-170 mJ). Supported by the surface morphological result, it can be concluded that the radiated thin films, which have lowest resistivity have smoother surface than the as-deposited sample.

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References

[1] Z. Li, P. Beck, D. A. A. Ohlberg, D. R. Stewart, and R. S. Williams (2003). Surface properties of platinum thin films as a function of plasma treatment conditions," *Surface. Science.*, vol. 529, no. 3, pp. 410–418.

[2] P. Panda *et al.* (2017). Reduction of residual stress in AlN thin fi lms synthesized by magnetron sputtering technique. *Material Chemistry Physics*, vol. 200, pp. 78–84.

[3] Ahmad Hadi Ali, Zainuriah Hassan and Ahmad Shuhaimi (2016). High figure of merit of the post-annealed Ti / Al / ITO transparent conductive contacts sputter deposited on n-GaN. *Journal of Alloys and Compounds*, vol. 681, pp. 186–190.

[4] M. Abd and E. Qader (2011). Structural, electrical and thermoelectric properties of chromium silicate thin films. *UNLV Theses, Dissertations*, Professional Papers, and Capstones. 1222.

[5] A. H. Ali, A. Shuhaimi, Z. Hassan, and Y. Yusof (2013). Compositional and Structural Characterization of Heterostructure InGaN-based Light-Emitting Diode by High Resolution X-Ray Diffraction. *Advanced Materials Research*. vol. 620, pp. 22–27.

[6] Bandar Astinchap, Rostam Moradian, Katayon Gholami (2017). Effect of sputtering power on optical properties of prepared TiO2 thin films by thermal oxidation of sputtered Ti layers. *Materials Science in Semiconductor Processing*, Volume 63, p. 169-175.

[7] N. P. Barnes (1995). Tunable Lasers Handbook: 6 - Transition Metal Solid-State Lasers. A volume in Optics and Photonics. Academic Press. p. 219-291.

[8] M. Z. Butt, D. Ali, M. U. Tanveer, and S. Naseem (2015). Surface roughness and electrical resistivity of high-purity zinc irradiated with Nd : YAG laser pulses. *Materials Today: Proceedings*, vol. 2, no. 10. p. 5587-5591.

[9] Mirza Khurram Baig, Shahid Atiq, Shazia Bashir, Saira Riaz, Shahzad Naseem, Hassan Soleimani, Noorhana Yahya (2016). Pulsed laser deposition of SmCo thin films for MEMS applications. *Journal Applied Research Technology*, vol. 14, no. 5, p. 287-292.

[10] A. I. Khudiar, M. Zulfequar, and Z. H. Khan (2009). Laser radiation effects on optical and structural properties of nanostructure CdSe thin film," *Radiat. Eff. Defects Solids*, vol. 164, no. 9, pp. 551–560.

[11] H. Salar Amoli and B. Fathi (2011). Effect of pulse Nd-YAG laser beam interaction on annealing of nanopowder ITO using spin-on-glass," *J. Sol-Gel Sci. Technol.*, vol. 59, no. 1, pp. 32–35.